Analyzing timber-price uncertainty in forest planning
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Abstract

Variation in timber prices is a major source of uncertainty in tactical forest planning. In this study, uncertainty is measured by using stochastic timber-price scenarios over the planning period. The simulation model is constructed on the basis of observed timber prices in Finland, including the possibility of price peaks, i.e. exceptionally high timber prices paid in the early 1950s and mid-1970s. It is also demonstrated how expert judgment can be incorporated in model construction so that the model also includes information external to the past history. When using timber-price scenarios in forest planning calculations, one should take into account that timber sellers adapt their timber sales transactions to variable timber prices. Therefore, it is stated here that the assumption of timber selling decisions independent of stochastic timber prices can lead to underestimation of the possibilities to obtain timber-harvesting incomes and to excessive harvest-removal recommendations. An analogous bias would arise if one were to use deterministic timber prices instead of stochastic ones.

1 Introduction

The aim of forest planning is to produce an action plan that fulfills the objectives of the forest owner as well as possible. The time period of forest planning is quite long, e.g. in tactical forest planning it typically varies from 5 to 20 years.

The problem of forest planning in private forestry can be formulated as that of finding out a plan that maximizes the utility of the
forest owner. However, due to uncertainty, the utility produced by different decision alternatives cannot be accurately computed. Success of regeneration, growth, survival of trees, development of timber prices, and difficulties in preference analysis are the main sources of uncertainty in forest planning.

The uncertainty of timber prices can be taken into account by simulating stochastic timber-price scenarios over the planning period. Simulated timber prices are used to compute the utility distribution produced by alternative forest plans, and this in turn enables one to choose the optimal forest plan under uncertainty (Pukkala & Kangas [7]).

This paper discusses the time-series model needed for simulating timber-price scenarios as well as the means of utilizing expert judgment in model construction. Also, the effects of adaptive timber selling are put forward.

2 Simulation model

Leskinen & Kangas [3] constructed a time series model for year-specific average timber prices in Finland for different types of timber (Figs. 1 and 2). A special feature of timber prices is the occurrence of price peaks, i.e. exceptionally high timber prices, in the early 1950s and mid-1970s. Therefore, the simulation model consists of two different processes, one for price peaks, and the other for the rest of the time series.

Let \( X_t \) be the logarithmic timber price in year \( t \) once price peaks have been eliminated. The simplest appropriate model for \( X_t \) is AR(1), i.e.

\[
X_t - \bar{X} = \alpha (X_{t-1} - \bar{X}) + Z_t, \tag{1}
\]

where \( \bar{X} \) is the average of \( X_t \) and \( Z_t \sim NID(0, \sigma^2) \), or \( Z_t \) are an independently and normally distributed random variables with a mean zero and variance \( \sigma^2 \). When \( |\alpha| < 1 \), the process is stationary.

The price series for different types of timber are cross-correlated. This can be taken into account by estimating the cross-correlation
structure of $Z_t$ between different time series, and by using the Cholesky decomposition to simulate it (e.g. Ripley [8]).

The occurrence of price peaks will be taken as Bernoulli trial, i.e. a price peak occurs in year $t$ with a probability of $p$, or it does not occur with a probability $1 - p$. A normal distribution is used to generate the effect of a price peak. Price peaks may also have an effect over several years. The decreasing effect of a price peak in year $t = t_0$ with lag $i$, $V_{t_0+i}$, will be modelled as

$$V_{t_0+i} = \phi^i V_{t_0} + \eta_{t_0+i},$$

where $0 \leq \phi < 1$, $V_{t_0}$ is the effect of a price peak, and $\eta_{t_0+i} \sim \text{NID}(0, \sigma^2)$. 

3 Expert judgment

The construction of the simulation model was based on observed data and it can be used to mimic past variation in timber prices. However, it does not necessarily give the best possible description of future timber prices, because information external to observed price data is not utilized in the model. Moreover, the parameter estimates of the simulation model are based on a small number of observations and are therefore uncertain. This is obviously the case with price peak parameters, but it also holds for the rest of the time series. For example, Chatfield [1] points out that in order to identify a suitable ARIMA model, at least fifty observations should be available. Utilization of expert judgment is a way to introduce new information about potential future events into a time-series model, and to increase the credibility of parameter estimates.

In Finland, timber prices in the 1980s and early 1990s used to be based on a price-agreement system between buyers and sellers. One aim of the system was to decrease price variation. Since the early 1990s, the system has been extensively modified. Therefore, one potential use for expert judgment is in evaluating the magnitude of future price variation.
The parameter for timber price variation in Eq. (1) is residual variance $\sigma^2$. However, it is not worthwhile asking an expert directly for the magnitude of $\sigma^2$, because the residual variance of the model AR(1) for logarithmic timber prices is not readily comprehensible as a concept to the expert. Instead, it would be more convenient for the expert to give his/her opinion of the probability that future timber prices will stay between some upper limit $U$, and a lower limit $L$. Let us assume that the expert gives a probability 0.95, when $\log(U) - \log(L) = 0.4$. By using a normal distribution, we obtain that $0.4 = 2 \cdot 1.96 \cdot \sqrt{\text{Var}(X_t - \bar{X})}$. This, and assuming $\alpha$ to be fixed, enables us to solve $\sigma^2$, because (e.g. Chatfield [1])

$$\text{Var}(X_t - \bar{X}) = \frac{\sigma^2}{1 - \alpha^2}. \quad (3)$$

It is also possible to compute the probabilities associated with the limits $U$ and $L$ by using the observed data divided among different estimation periods according to changes in the price-agreement system. These probabilities can be used as reference values by the expert so that he/she will have a view of the potential scale of price variation.

In addition to $\sigma^2$, expert judgment can be utilized for other parameters as well. For example, the estimate of probability $p$ for price peaks would need support from judgment, and although a time trend is not used for observed data, it might be needed when dealing with the future.

4 Adaptive timber selling

When using timber-price scenarios in forest planning calculations, it should be taken into account that forest owners do not necessarily sell timber independently of timber prices, but instead adapt their timber sales transactions according to price fluctuations. For example, Ollonqvist & Heikkinen [5] found differences among forest owners with respect to the economic profitability of timber sales depending on their motives of timber selling.
Leskinen et al. [4] studied the effects of stochastic timber prices on the choice of forest plan at the forest area level, and evaluated the benefits, which the forest owner might gain through adaptive timber selling. They compared differences between the values of criterion variables in adaptive optima under stochastic timber prices to the optimum under deterministic timber prices (anticipatory optimum). Here, the term adaptive optimum refers to the treatment schedule maximizing the utility when simulated timber prices of the simulation round in question are known. Thus, adaptive optima give the maximum outputs achievable from the forest area under study. Although the maximum is not possible to achieve in practice, it can be used to evaluate the upper limit of the gains brought about by adaptive timber sales. The anticipatory optimum corresponds to the current forest planning practice.

The results of the case study by Leskinen et al. [4] were that the mean value of the adaptive optima of criterion variables is systematically different from the anticipatory optimum. In the case study, the mean net present value of the income and costs of the first planning period \((NPV_1)\), for example, were between 14% and 36% higher in the adaptive optima than in the anticipatory optimum depending on the assumptions embodied in the timber-price model. Correspondingly, the mean adaptive optima for the volume of saw logs at the end of the second planning period \((LOG_2)\), were between 12% and 62% higher than in the anticipatory optimum. Secondly, the variation of the optimal values of the adaptive optima was large, e.g. the volume of the growing stock at the end of the second planning period \((VOL_2)\) varied from 10 000 to 20 000 m\(^3\).

5 Discussion

Although expert judgment is a way to increase the credibility of the parameter estimates in the simulation model, the estimates still remain uncertain. For example, the probability of the occurrence of a price peak can not be known with certainty regardless of expert judgment. At the same time, however, price peaks may have considerable impacts on the choice of optimal forest plan. Also, the parameters of the AR(1) model
are uncertain, and even the question of whether to use AR(1), or perhaps some other time-series model remains unsolved.

Analysis of the uncertainty of timber prices can be extended from residual variance simulation to include also ambiguity of the parameters. In a Bayesian framework (e.g. Press [6]), the observed time series could be used as prior information and a posterior distribution can be formed by using also expert judgments. If the distributional assumptions, too, are unsure, interval analysis could be used (Ferson & Ginzburg [2]).

The effect of timber-price uncertainty in forest planning is considerable even under the current setting, because optimal management strategy is highly dependent on timber prices. If the adaptive timber-selling behaviour of forest owners is neglected, or if timber prices are assumed to be constant, the possibilities to obtain timber-harvesting incomes will be underestimated. This, in turn, leads to excessive harvest-removal recommendations, assuming that the income objectives of the forest owner remain fixed.

References


Figure 1: Real timber prices for sawlog species.

Figure 2: Real timber prices for pulpwood species.